SANTA CLARA VALLEY WATER DISTRICT

LLAGAS GROUNDWATER BASIN NITRATE STUDY

SAMPLE POINT SELECTION

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LLAGAS GROUNDWATER BASIN NITRATE STUDY

CONTRACT NO. 1-053-250-0

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DECEMBER 1994

This project has been funded wholly on in part by the United States Environmental Protection Agency using Section 205(j) grant funds under Assistance Agreement C6009585-91-1 to the State Water Resources Control Board and by Contract No. 1-053-250-0 in the amount of $33, 823 to conduct a water quality management planning study to develop recommendations for prevention and control of nitrate in the Llagas Groundwater Basin. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency or the State Water Resources Control Board, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use.

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I. EXECUTIVE SUMMARY

Communities in the southern portion of Santa Clara County rely solely on groundwater from Llagas Basin for their water supply. Over the years, groundwater from municipal and private water supply wells has been found to contain concentrations of nitrate greater than those allowed by federal safe drinking water standards. The Santa Clara Valley Water District (District), as well as other local agencies, is concerned with the elevated nitrate concentrations in Llagas Basin, and as a result, is conducting the Llagas Groundwater Basin Nitrate Study.

The present Maximum Contaminant Level (MCL) for nitrate in drinking water is 45 milligrams per liter (mg/l), as promulgated by the United States Environmental Protection Agency (USEPA). Higher concentrations of nitrate have been known to cause adverse health effects in infants.

Measures are being taken to ensure that drinking water standards for nitrate are being met. Affected municipal water supply wells are either no longer used or the groundwater from them is blended with groundwater from other wells containing lower concentrations of nitrate. Also, some of the private wells are using wellhead treatment systems to remove nitrates from the water.

The District is responsible for managing the groundwater basin to ensure its viability as a long term potable water supply. This study is exploring nitrate exposure prevention and source reduction alternatives and will recommend a specific nitrate management plan for the Llagas Groundwater Basin.

The study is being performed in the following phases: (1) review of historic nitrate data, (2) identification of categories of nitrate sources, (3) field sample collection, (4) evaluation of groundwater analytical results, and (5) development of a Nitrate Management Plan. During the first phase of work, the District evaluated historical nitrate concentrations in the groundwater of the study area. These evaluations are found in the study report "Nitrate Data Review" dated August 1993. During the second phase of the study, the District identified sources of nitrate contamination in the study area and reported the results in the report "Nitrate Source Area Identification" dated December 1994. During the phase of the study described in this report, the District determined locations for groundwater sample collection. This report contains a summary of the methodology for selecting nitrate sample collection points and contains a map showing the locations of the sample collection points that were selected. Subsequent phases of the study will focus on collecting new groundwater quality data, and developing alternative strategies for reducing nitrate concentrations in order to continue providing a water supply that meets safe drinking water standards to the people of Llagas Basin. The overall nitrate study is scheduled for completion in March of 1995.

A Technical Advisory Committee (TAC), including members of the community, has been assisting the District throughout the study, but is expected to provide the most input during the development of the Nitrate Management Plan.

LLAGAS BASIN GROUNDWATER FLOW

Llagas Basin has two hydrogeologic regions. One region is referred to as the forebay region, where rainfall and artificially recharged water percolates through the ground directly into the underlying aquifer. The forebay region is located in the northern part of Llagas Basin. The second region is known as the confined region and is located in the southern part of Llagas Basin.

In the confined region, a thick clay layer, known as an aquitard, separates the deeper water producing aquifers from shallow aquifers. Groundwater on top of this clay layer is primarily from rainfall, whereas groundwater flowing underneath the clay layer primarily originates in the forebay region. There is some vertical interconnection between these aquifers through old wells that may be screened in both shallow and deep aquifers. Other potential vertical connections between the aquifers include rootholes and geologic discontinuities.

The direction of groundwater flow in Llagas Basin is primarily south towards the Pajaro River. Due to the variable characteristics of the basin, the depth to ground water below ground surface differs throughout the basin but normally ranges from between 10 to 70 feet below ground surface.

FORMATION AND TRANSPORT OF NITRATES

Nitrate is produced when compounds which contain nitrogen (human and livestock waste, agricultural fertilizers, etc.) are introduced into the environment where they are transformed into nitrate in the soil via mineralization and nitrification. Mineralization is the process of organic nitrogen compounds being transformed into inorganic nitrogen compounds such as ammonium salts. Nitrification is the process of bacteria transforming those inorganic nitrogen compounds into nitrates. Except for certain chemical reactions that form minor amounts of nitrate from oxides of nitrogen in the atmosphere, this biological nitrification of nitrogenous compounds is the sole source of nitrate in the environment.

Once nitrogen containing compounds have been transformed into nitrate through mineralization and nitrification, the nitrate can dissolve in water percolating through the soil and be transported downward into groundwater aquifers. As stated in the "Identification and Evaluation of Methods for Determining Sources of Nitrate Contamination in Groundwater: Guidance Manual" by Rolston, et. al. (Guidance Manual), it can take anywhere between 10 to 100 years for nitrate to travel through the vadose zone and reach groundwater. The vertical migration of nitrate is dependent on the amount of water infiltrating the soil, the soil type, and the depth to groundwater.

Because it may take a considerable amount of time for nitrate to be transported to groundwater, nitrates found in groundwater today may have originated from previous sources which are not reflected in current land uses. Though some practices which generate nitrate have been discontinued, groundwater quality may still be affected over time due to the transport of dissolved nitrates in water percolating through the soil. The time required for the movement of nitrate from the ground surface to groundwater depends on local conditions related to precipitation, transport in soil, plant nitrate uptake, and other processes. The nitrates which are found in groundwater today may have been released from the soil over several years or decades. Thus, soil containing high nitrate concentrations may still be considered sources of nitrate contamination to groundwater even though the practices that originally released the nitrogen to the soil have been discontinued.

METHODOLOGY FOR SAMPLE COLLECTION POINT SELECTION

The main goals of selecting the wells to be sampled during this study were to generate groundwater quality information to assess nitrogen contributions from various sources, to continue nitrate concentration trend analysis, and to provide us with general groundwater quality information. The selection process was challenging due to the large number of water wells in Llagas Basin. More than 3,900 water wells exist in Santa Clara County south of Metcalf Road. It is estimated that 80 percent of these wells are located in Llagas Basin, and little information is available for the majority of these wells. Our approach to select the wells was to assign a value to the various well characteristics that were deemed important for groundwater quality purposes. Then we ranked each of the wells based on their respective characteristics. Some of the well characteristics we considered were: well location in the study area, well location relative to possible nitrate sources, well condition and status, availability of well construction information, availability of previous nitrate sampling results, and well screen depths.

We believe that following the groundwater well sampling protocol outlined in this study's Quality Assurance Project Plan will allow us to collect representative samples from each well.

LIMITATIONS OF SAMPLE COLLECTION POINT SELECTION

Despite the large number of water supply wells in Llagas Basin, we discovered during our selection process that complete well construction information was available for only a very few wells for our study purposes. Although construction information was available for over a third of the wells in the study area, we selected some wells without construction information due to the wells' appropriate locations in the basin or locations relative to nitrate sources. Very few of the wells which had a significant number of previous nitrate results also had available construction information. This fact limited the conclusions which could be drawn from previous sampling rounds, by preventing us from collecting samples for our study which could confirm which aquifer contains high nitrate water. Continuation of nitrate trend analysis in specific aquifers was also precluded. Two wells which are completed only in first encountered shallow groundwater were selected to specifically monitor that zone. Collecting samples from above the confining layer may also help our evaluation of the sources of nitrate in well water in the southern area of Llagas Basin.

CONCLUSIONS

A total of 28 groundwater wells were selected through the process described in this report. Some of the wells will be sampled for the specific purpose of monitoring groundwater quality up and downgradient of various suspected nitrate source areas. Several of the wells selected for sampling are intended to provide recent nitrate concentration data to add to historical data already compiled for those wells. Other wells will be sampled to monitor shallow and background groundwater quality. After all the wells are sampled during the next phase of the study, the results will be used to help develop recommendations in our Nitrate Management Plan.

II. INTRODUCTION

The Llagas Groundwater Basin Nitrate Study is being conducted by the Santa Clara Valley Water District (District) with partial funding from the State Water Resources Control Board (SWRCB) because the District has observed a general trend of increasing nitrate concentrations in Llagas Basin groundwater. The purpose of this phase of the study is to determine locations for groundwater sample collection in Llagas Basin. Subsequent phases of the study will focus on collecting current nitrate concentration data to verify long term trends and developing and recommending an implementation plan for the prevention and control of nitrates.

The southern portion of Santa Clara County, including the cities of Morgan Hill and Gilroy, and the area of San Martin, depends solely on the groundwater from Llagas Basin for its drinking and irrigation water supply. Figure 1 shows the location of the Llagas Basin study area. Current land use distribution in the Llagas Basin area is as follows: about 40 percent agricultural area, 25 percent Urban Service area, 20 percent Rural Residential area, and 5 percent parks and open space. The remaining 10 percent of the land has various land use classifications such as Public Transportation, Educational/Institutional, and Public Facilities. These percentages are based on Santa Clara County's 1991 "Land Use Plan" and have been verified by Santa Clara County Department of Planning and Development staff (personal communication, 1993).

NITRATE HEALTH EFFECTS

The present Maximum Contaminant Level (MCL) for nitrate in drinking water is 45 milligrams per liter (mg/l), as promulgated by the United States Environmental Protection Agency (USEPA). Drinking water supplies with concentrations exceeding this level are considered out of compliance, and require treatment and/or alternative supplies.

In Llagas Basin, numerous wells have exceeded the federal MCL of 45 mg/l. As outlined in the District's "Nitrate Data Review" report, one third of the wells that have been sampled in Llagas Basin contained nitrate in concentrations above the 45 mg/l MCL. Nitrate concentrations exceeded 100 mg/l at several locations. Elevated nitrate concentrations are a concern because of the susceptibility of infants to methemoglobinemia (blue baby syndrome) resulting from exposures to higher levels of nitrates in water. In addition, research is being done to determine whether excess nitrates in food and drinking water might also have long term carcinogenic (tendency to cause cancer) or teratogenic (tendency to cause fetal malformations) effects on exposed populations.

FORMATION AND TRANSPORT OF NITRATES

Nitrate is produced when compounds which contain nitrogen (human and livestock waste, agricultural fertilizers, etc.) are introduced into the environment and transformed into nitrate in the soil via mineralization and nitrification. Mineralization is the process of organic nitrogen compounds being transformed into inorganic nitrogen compounds such as ammonium salts. Nitrification is the process of bacteria transforming those inorganic nitrogen compounds into nitrates. Except for certain chemical reactions that form minor amounts of nitrate from oxides of nitrogen in the atmosphere, this biological nitrification of nitrogenous compounds is the sole source of nitrate in the environment.

Nitrogen is introduced into the environment from a variety of sources. In a 1976 study conducted by Miller and Smith for the San Joaquin River Basin in the San Joaquin Valley, California, seven primary nitrogen sources were identified. The sources included municipal wastes, industrial wastes, livestock manures, agricultural fertilizers, waterborne nitrogen (nitrogen bearing water entering the study area via stream and groundwater flow), nitrogen fixation (reduction of nitrogen gas to ammonia and organic nitrogen by various microorganisms), and precipitation. Results from the study reported nitrogen contributions from the various sources as follows: municipal wastes—2 percent, industrial wastes—4 percent, livestock manures—18 percent, agricultural fertilizers—43 percent, waterborne nitrogen—13 percent, nitrogen fixation—18 percent, and precipitation—2 percent. Because we find many of the same land use types in Llagas Basin, we have found that many of the same sources of nitrogen are significant contributors to Llagas Basin. It should be noted, however, that Llagas Basin is more urbanized than the San Joaquin Basin and therefore, the relative amounts of nitrogen introduced by municipal wastes (i.e. septic tank and wastewater treatment plant effluent) is expected to be higher.

Once nitrogen containing compounds have been transformed into nitrate through mineralization and nitrification, the nitrate can dissolve in water percolating through the soil and be transported downward into groundwater aquifers. It can take a considerable amount of time for nitrate to reach groundwater because the vertical migration of nitrate is dependent on the amount of water infiltrating the soil, the soil type, and the depth to groundwater. After nitrates reach groundwater they typically move in the direction of groundwater flow.

OVERALL STUDY TASKS AND STATUS

The study started on October 1, 1991, and is scheduled to be completed on March 31, 1995. The agreement between the SWRCB and the District for the study consists of the following eleven tasks:

- Manage and Administer Project. This is an ongoing task.
- Conduct Public Participation Meetings. One out of two meetings has been held.
- Develop Quality Assurance Project Plan. This task has been completed.
- Review Historical Nitrate Data. This task has been completed.
- Identify Nitrate Source Categories. This task has been completed.
- Select Sample Collection Points[1]
- Collect and Analyze Samples and Data
- Review Legislative Mechanisms and Management Plan to Control the Nitrate Problem
- Prepare Implementation, Institutional, and Financial Plans
- Prepare Draft Final Report
- Prepare Final Report

Three of the tasks have already been completed. These tasks include developing a Quality Assurance Project Plan; completing the "Nitrate Data Review" report, which summarized and evaluated nitrate data from previous studies; and completing the "Nitrate Source Area Identification" report that identified and attempted to quantify the sources of nitrate present in Llagas Basin. The remaining tasks include sampling and analyzing groundwater from selected wells and developing a plan for the prevention and control of nitrates. A review of existing and potential legislative mechanisms for controlling nitrates is being performed with input from a Technical Advisory Committee (TAC). The TAC is composed of representatives from the SWRCB, the Central Coast Regional Water Quality Control Board (CCRWQCB), the cities of Gilroy and Morgan Hill, and the County of Santa Clara.

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[1] Present status of study

METHODOLOGY FOR SAMPLE COLLECTION POINT SELECTION

The main goals of selecting the wells to be sampled during this study were to generate groundwater quality information to assess nitrogen contributions from various sources, to continue nitrate concentration trend analysis, and to provide us with general groundwater quality information. The selection process was challenging due to the large number of water wells in Llagas Basin. More than 3,900 water wells exist in Santa Clara County south of Metcalf Road. It is estimated that 80 percent of these wells are located in Llagas Basin, and little information is available for the majority of these wells. Our approach to select the wells was to assign a value to the various well characteristics that were deemed important for groundwater quality purposes. Then we ranked each of the wells based on their respective characteristics. Some of the well characteristics we considered were: well location in the study area, well location relative to possible nitrate sources, well condition and status, availability of well construction information, availability of previous nitrate sampling results, and well screen depths.

LIMITATIONS OF SAMPLE COLLECTION POINT SELECTION

Despite the large number of water supply wells in Llagas Basin, we discovered during our selection process that complete well construction information was available for only a very few wells for our study purposes. Although construction information was available for over a third of the wells in the study area, we selected some wells without construction information due to the wells' appropriate locations in the basin or locations relative to nitrate sources. Very few of the wells which had a significant number of previous nitrate results also had available construction information. This fact limited the conclusions which could be drawn from previous sampling rounds, by preventing us from collecting samples for our study which could confirm which aquifer contains high nitrate water. Continuation of nitrate trend analysis in specific aquifers was also precluded. Two wells which are completed only in first encountered shallow groundwater were selected to specifically monitor that zone. Collecting samples from above the confining layer may also help our evaluation of the sources of nitrate in well water in the southern area of Llagas Basin.

III. GEOLOGY AND HYDROGEOLOGY OF LLAGAS BASIN

The geologic history of Llagas Basin has resulted in a complex hydrogeologic system consisting of confined and unconfined aquifers. As shown in Figure 1, Llagas Basin continues southeasterly from the southern end of Coyote Valley at the interconnecting topographic divide to the southern boundary of the County at the Pajaro River. The bulk of the alluvial materials washed into the basin is alluvial fan materials from Coyote Creek splaying southward from the topographic divide. Other major sources of alluvial fill material that constitute the basin are from Llagas Creek and Uvas Creek from the Santa Cruz Mountains which bound the west side of the basin. Small alluvial fans from small ephemeral drainage occur along both elevated lateral edges of the basin. As shown in Figure 2, the depth of alluvial fill and the underlying Santa Clara formation varies from about 500 feet at the northern divide to greater than 1,000 feet at its southern end. The Purissima Formation which underlies the alluvium and the Santa Clara Formation is, in part, water bearing in neighboring counties, but is not tapped here.

In general, the basin is divided into three hydrographic units. The northern portion of the basin and the elevated lateral edges of the basin constitute the forebay and the southern flat interior portion is divided into upper and lower aquifer zones (similar to Santa Clara Valley Basin).

The forebay comprises mostly aquifer materials with discontinuous aquitards, is unconfined, and is the principal basin recharge zone. Recharge is from subsurface inflow from Coyote Valley where a groundwater mound occurs beneath the topographic divide, from deep percolation of streams, principally along Llagas Creek north of Rucker Avenue, and from Uvas Creek west of U.S. Highway 101. Minor amounts of recharge can also be attributed to rainfall, irrigation returns, and from the subsurface flow from nonwater-bearing formations that laterally bind the basin. Within the forebay, groundwater generally flows from the topographic divide southeasterly down the basin toward the flat south central part of the basin.

Confining conditions which create both upper and lower aquifer zones occur in the flat southern interior portion of the basin and continue southerly past the County line into the Hollister Basin. The separation between the upper and lower aquifers is formed by a continuous regional aquitard that occurs at varying depths from about 20 to 100 feet, and extends from approximately Rucker Avenue to the south basin boundary. The thickness of this major aquitard varies from about 40 to 100 feet. Both upper and lower zones are stratified with aquifers and aquitards.

Groundwater in the upper aquifer zone is unconfined in the uppermost aquifer and confined or partially confined in deeper aquifers. The depth to groundwater in this zone is usually shallow and generally flows southeasterly, to the Pajaro River. Recharge to the upper aquifer zone is from surface sources and from subsurface flows from the forebay.

Numerous individual aquifers occur in the lower aquifer zone. Groundwater in these aquifers is confined and generally flows to the southeast except where the regional gradient is interrupted by pumping troughs. Subsurface flow from the forebay recharges these aquifers. From the mid-1800s, wells tapping the southern portion of this zone, south of Old Gilroy, were flowing artesian wells (Clark, 1924). With a greater amount of pumping in more recent times in proportion to growing water demands, the artesian pressures have declined and now only a few of the wells in the southernmost portion of the basin flow under pressure; these are only on a seasonal basis.

In Llagas Basin most of the waters are pumped from the forebay and lower aquifer zones, though many of the wells in the flat southern interior portion of the basin pump from both upper and lower aquifer zones[2].

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[2] Additional discussion of Llagas Basin geology and hydrogeology is available in the May 1981 "Evaluation of Ground Water Resources: South San Francisco Bay. Volume IV: South Santa Clara County Area," by the Department of Water Resources (Bulletin 118-1).

IV. PURPOSE OF SAMPLING POINTS

The general purpose of sampling groundwater wells in the study area for nitrates and other pertinent parameters is to provide additional data in order to develop the Nitrate Management Plan. The data obtained from the wells sampled in Llagas Basin is intended to supplement the information gathered during the historical nitrate data review and source identification portions of the study. The specific purposes described below were selected with the goal of the entire study in mind.

SPECIFIC PURPOSES

There are three purposes for which additional sample data was required. The first purpose was to monitor groundwater quality in the vicinity of known source areas. Results of the sampling will be evaluated in conjunction with information presented in the "Nitrate Source Area Identification" report dated December 1994, to see if any correlations can be drawn between nitrate sources and concentrations in the study area.

Our second purpose was to fill in gaps, if any, in areal data. Evaluations in the "Nitrate Data Review" report were used to determine whether or not, and where, additional data points were needed to supplement existing data.

Our third purpose was to resample wells as part of our program to continue trend analysis. Several wells were presented in the "Nitrate Data Review" report as "example wells." These wells had a large number of nitrate results collected over a long time period and were used to determine nitrate trends in the groundwater of Llagas Basin. Other wells which have numerous historical data points and were not presented as "example wells" in our "Nitrate Data Review" report, dated August 1993, were also used to evaluate nitrate trends.

DISCUSSION

We decided not to sample any wells for the specific purpose of filling in gaps in areal data. This decision was made based on a review of the areal coverage provided by historical nitrate data. There appear to be no large areas or unique significant land use areas which have not been sampled for nitrate in the past.

In order to optimize the data collected from our sampling program, we decided to concentrate on the other specific purposes discussed above. Selection of wells for these purposes involved consideration of several factors which are described in the next section.

V. FACTORS AFFECTING WELL SELECTION

Since we wanted the selected wells to serve the two specific purposes described in the previous section, all possible factors were considered for the well selection procedure. However, we primarily considered those factors which influence groundwater quality data the most. We originally identified seven primary factors: (1) nitrate sources, (2) hydrogeologic parameters, (3) historical nitrate data, (4) well construction information, (5) well status, (6) historical groundwater elevation data, and (7) well logs. However, due to insufficient information, some of the factors were eliminated from the well selection process. The following paragraphs discuss the factors we identified and considered when determining the location of sample collection points.

NITRATE SOURCES

One of the specific purposes of our selected wells was to monitor groundwater quality in the area of potential sources. In order to adequately monitor a potential source, we first determined whether the source was a point or nonpoint source and attempted to determine how long nitrate discharges from that source may have occurred. Whether or not a suspected nitrate source can be classified as point or nonpoint was important to determine because this factor affected the number and location of sample points needed to monitor the particular source. Because nonpoint sources are, by definition, diffuse, many wells may be required to adequately monitor them. Conversely, point sources can often be adequately monitored with only two wells: one upgradient and one downgradient.

Whenever possible, we determined how long any nitrate discharges occurred. A nitrate source that has been releasing nitrate for a long period of time can be expected to have a greater impact to groundwater than a source of equivalent intensity that only discharged nitrate over a short time interval.

We attempted to choose sample points which are relatively near to the source and were within the groundwater flow lines. It is important to choose sample points that are near the source to increase the likelihood of monitoring groundwater directly affected by the source.

HYDROGEOLOGIC PARAMETERS

We considered hydrogeologic conditions when selecting potential sample points because nitrate is transported in the soil by water. Vadose zone stratigraphy, local groundwater flow direction, and where in the basin a nitrate source is located (forebay or confined zone) are all important hydrogeologic parameters that were considered while selecting nitrate sample points.

Whether a source is located in the forebay zone or in the confined zone is an important consideration. If a source is located in the forebay zone, nitrate will typically not be hindered from reaching deep groundwater aquifers. Conversely, if a source is located in the confined zone, vertical migration may be hindered by confining layers called aquitards, and nitrate may not reach the deeper aquifers. Groundwater samples collected from deep groundwater aquifers may not necessarily contain nitrate that has originated at sources above the aquitards because the nitrate may not have been able to move through them; nitrate present in the lower zone of the confined area of the basin may have originated in recharge areas located in the forebay. A major exception is when artificial conduits such as abandoned wells are present to circumvent any naturally occurring hindrance to migration.

Groundwater flow direction in the vicinity of a nitrate source was also an important factor to consider. Once nitrate enters groundwater, it will likely be transported with groundwater. It was therefore necessary to understand the groundwater flow direction so that sample points may be selected in locations where nitrate is expected to have migrated as well as in locations that should not have been impacted, both up and downgradient of a source. The highest concentrations of nitrate are expected to occur downgradient of the location where the nitrate enters the groundwater. General groundwater flow direction was the major consideration in determining preferred locations for wells relative to potential sources.

It is helpful to study vadose zone stratigraphy in site-specific detail when selecting a sample point. The transport of nitrate in the vadose zone is controlled by soil stratigraphy. As nitrate is transported downward to groundwater from the ground surface, it must pass through layers of soil, each with specific properties that determine how fast water and nitrate can move through it. If water moving downward encounters a layer which impedes its vertical flow, it may begin to move horizontally in the direction the layer dips. This horizontal transport may result in nitrate begin transported in directions that are not necessarily the same as groundwater flow in the deeper, saturated zones. This may result in nitrate reaching groundwater at a location that may not be the most likely area for high contamination, based on a determination of the local groundwater flow direction. Consideration of vadose zone stratigraphy can help determine where nitrate can be expected to reach groundwater and, therefore, can aid in selecting appropriate groundwater sampling points. This was not possible during our well selection process due to the general lack of well-specific geologic information.

HISTORICAL NITRATE DATA

As discussed above, all wells which were used as "example wells[3]" in the District's "Nitrate Data Review" report were intended to be sampled during this study to continue data trends in those wells. Due to well registration and access difficulties, however, only three of those six wells can be resampled for this study. Three other wells for which a significant number of data points were available were sampled, to allow for a total of six wells included in our program for the purposes of continuing trend analysis.

The important factors we considered when reviewing historical data are: how often data was collected, how much data was collected, and how consistent the data appeared to be. We wanted to consider information about quality assurance/quality control (QA/QC) measures taken and recorded during the historical sample collection episodes. However, very little QA/QC information was available.

WELL CONSTRUCTION INFORMATION

Well construction information is an important factor to consider when selecting sample points. Without well construction information it is difficult to determine from what depth in an aquifer a groundwater sample is being collected. Water may be drawn from any depth interval with which a well's gravel pack is in contact. The most important well construction parameters that should be considered are total well depth and well screening intervals. The availability of well construction information was a major deciding factor when selecting wells for our sampling.

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[3] Example Wells—those wells whose historical sampling requests were used to illustrate data trends in the "Nitrate Date Review" report.

Also, wells that had both well construction information and historical nitrate data were evaluated to determine whether the construction of the well affected the nitrate concentrations. No correlation could be made between nitrate data and well construction information as very few wells had both well construction information and historical nitrate data.

WELL STATUS

Before selecting a well as a potential sample point, we determined whether it was possible to sample it. Wells not containing pumps, registered as destroyed, or unregistered, were not selected as sample points. We selected domestic wells as sample points when possible; gaining access to domestic wells is typically easier than gaining access to agricultural, municipal, or industrial wells. Other factors considered when developing our list of sample collection points were the availability and cooperation of the well owner, and the times available for well sampling. We also ensured that each well preliminarily selected for sampling had a sample port or other suitable point for collecting a representative groundwater sample.

HISTORICAL GROUNDWATER ELEVATION DATA

Historical groundwater elevation data could be an important factor to examine because changes in groundwater elevation may have an effect on groundwater nitrate concentrations. Nitrogenous compounds which are contained in soils may end up as nitrate if groundwater if those soils become saturated. As discussed in our "Nitrate Data Review" report, only weak correlations between nitrate concentrations and water levels in wells for which such data was concurrently available could be drawn. However, we still considered water level information as a factor for selecting wells in our sampling program.

WELL LOGS

Highly localized stratigraphic information, such as that which would be obtained from drilling records for the wells we sampled, was not reviewed as part of our well selection process. Given the limited number of available well logs and the heterogeneity of the Llagas Basin geology, the limited information would not provide a solid basis in developing geologic assumptions.

VI. WELL SELECTION CRITERIA DEVELOPMENT

The following well selection criteria were developed from the seven factors described above for accomplishing the study purposes. This section describes and ranks the criteria with which sample collection points will be selected and identifies the well selection criteria judged to be the most important.

The following well selection criteria for each purpose are ranked in descending order of importance. The purposes were separated in this and the following sections because the criteria for these purposes are not necessarily the same.

POINT AND NONPOINT SOURCE SAMPLING—WELL SELECTION CRITERIA

The following criteria were used to determine which sample points would be selected to sample in the vicinity of point and nonpoint sources. The selection criteria are ranked in order of importance (with "a" being the most important criteria for determining whether a well should be sampled).

a. **Location of well with respect to source and regional groundwater flow direction.** The location of the sample collection point with respect to a source and the regional groundwater flow direction is the most important criteria to consider when selecting sample points. If a sample collection point is not located downgradient of the nitrate source, nitrate contamination that is being released from the source is less likely to be found.

b. **Availability of well construction information.** The availability of well construction information is important because without specific information about the construction of the well it is not possible to determine from what depth in the aquifer a sample is being collected.

c. **Distance of well from source.** The distance that a sample collection point is located from a source should be considered because the nitrate concentration will likely decrease with distance from the source. Distance is also important because the further away from the source that a sample is collected, the greater the chance that another unknown source will be located between the sample collection point and the source and will interfere with nitrate data.

d. **Well status.** It is important to consider if a well no longer exists, is not operating, or does not have a suitable sampling port. Also, cooperation of the well owner and the times available for well sampling should be considered.

e. **Availability of historical nitrate concentration data.** The existence of historical nitrate concentration data is not a mandatory criteria for selection of a sample collection point around a point or nonpoint source. If two potential sample collection points satisfy the above outlined criteria and one has historical nitrate concentration data associated with it, the well that has historical data should be selected.

TREND ANALYSIS SAMPLING—WELL SELECTION CRITERIA

An attempt was made to sample all "example wells" that were identified in the "Nitrate Data Review" report. The well status, cooperation of well owner, and well accessibility were thus the primary criteria used to determine whether an "example well" could be sampled. Three "example" wells were therefore able to be resampled.

Other wells with historical nitrate data were included as sample points because only half of the "example wells" could be sampled. The following are criteria that were used to determine which sample points would be selected for trend well sampling. As with previous sections, the selection criteria are ranked in order of importance (with "a" being the most important criteria for determining whether a well should be sampled).

a. **Availability of well construction information.** The availability of well construction information in important because without specific information about the construction of the wells it is not possible to determine at what depth in the aquifer a sample is being collected.

b. **Well status.** It is important to know if a well no longer exists, is not operating, or does not have a suitable sampling port. Also, cooperation of the well owner and the time available for well sampling should be considered.

VII. SOURCE RANKING PROCEDURE

The following procedure was used to select study areas for sample collection. As in Section VI, this procedure is discussed according to sampling purpose (e.g., source areas, example wells). This procedure is designed so that source areas and "example wells" will be selected for sampling. Backup wells were selected in cases where source areas or "example wells" were unavailable for sampling.

POINT AND NONPOINT SOURCE SAMPLING

The point and nonpoint study areas and their associated sample collection points were chosen according to the following procedure:

1. Sources were evaluated with respect to their maximum potential nitrate impact to the basin based on information in our "Nitrate Source Area Identification" report dated September 1993.
    - An attempt was made to choose no more than one study area from each source category identified in the "Nitrate Source Area Identification" report. Not all source categories were selected as study areas because only a limited number of sample collection points were to be included in this study.
2. The groundwater flow direction in the vicinity of each source was determined. Current and historical potentiometric surface contour maps were studied to determine the average groundwater flow direction vector for each site.
3. A search was made for wells with well construction details and an active status both up and downgradient, and within 1,000 feet, of the source.
4. A search was made for wells with historical nitrate data and an active status both up and downgradient, and within 1,000 feet, of the source.
5. A search was made for wells with historical groundwater elevation data and an active status both up and downgradient, and within 1,000 feet, of the source.
6. Based on the availability of information, the identified wells were then ranked according to the following criteria:

    LEVEL 1 WELLS: Wells which are located within approximately 500 feet of the identified source, have well construction details, have historical nitrate data, and have groundwater elevation data.

    LEVEL 2 WELLS: Wells which are located further than 500 feet of the identified source, have well construction details, have historical nitrate data, and have groundwater elevation data.

    LEVEL 3 WELLS: Wells which are located within approximately 500 feet of the identified source, and have well construction details only.

    LEVEL 4 WELLS: Wells which are located further than 500 feet of the identified source, and have well construction details only.

LEVEL 5 WELLS: Wells located within the proximity of a high priority source which have no well construction details, historical nitrate data, or groundwater elevation data. The necessity of sampling such a well would depend on the importance of the source as a potential nitrate contributor to the groundwater.

7. If none of the identified wells associated with a particular source could be ranked as above, another source was selected and the above procedure repeated for the new source.

8. The owners of any ranked wells were contacted to determine which wells could be sampled and are accessible, and to determine whether the owners would participate in the study.

9. If none of the wells that were associated with the source were accessible, another source was selected and the procedure was repeated.

10. Wells that had the highest rank and were accessible were selected for sampling.

TREND ANALYSIS SAMPLING

All "example wells" that were actively pumping and that were accessible were selected for sampling. This eliminated three of the six "example wells" available for sampling from our sampling program because they were no longer able to be sampled.

The following procedure was used to select "trend wells" for sampling:

1. Because not all "example wells" could be sampled, other wells that have abundant historical nitrate data associated with them were evaluated to determine whether they could be used as potential sample collection points. Wells with such data were identified as "trend wells." Information from these wells was evaluated for well construction details, active status, and historical groundwater elevation data. Based on the availability of the data, wells were selected and then ranked according to the following criteria:

   LEVEL 1 WELLS: "Trend wells" which have well construction details and groundwater elevation data available.

   LEVEL 2 WELLS: "Trend wells" which have well construction details available.

   LEVEL 3 WELLS: All other "trend wells."

2. Owners of all "trend wells" were contacted to determine which wells would be accessible and which well owners would be cooperative.

3. The three "trend wells" that had the highest rank and were accessible were selected for sampling. This number was selected to provide for a total of six "example" and "trend" wells, and provide for a balance of wells selected to monitor sources and those selected to monitor long term nitrate trends.

VIII. SELECTED WELLS

Table 1 includes a list of the 28 wells which were selected as sampling points for the study. The table also describes the source near which each well is located, or whether the well is an "example," "trend," or other type of well. As previously discussed, only a limited number of sample collection points were to be included in this study. Because of this, not all source categories that were identified in the "Nitrate Source Area Identification" report were selected as study areas. Only the sources that had the most appropriate sample collection points associated with them were selected as study areas.

Selecting six wells for trend analysis and most of the remainder of the selected wells for source area sampling allowed us to use most of the wells with a significant number of samples over the years, as well as monitor in the vicinity of most types of sources.

Also, a total of four wells were selected specifically for the purpose of monitoring general groundwater quality in Llagas Basin. Two wells were selected to monitor shallow groundwater quality; two wells were selected to monitor background groundwater quality in the hills, above the valley floor.

IX. ANALYTES

Groundwater from the 28 wells selected will be analyzed for the following analytes:

1. Nitrate
2. Nitrite
3. Dissolved Oxygen
4. Stable Nitrogen Isotope Analysis ($\delta^{15}N$)
5. Stable Oxygen Isotope Analysis ($\delta^{18}O$)
6. Total Kjeldahl Nitrogen (TKN)
7. Ammonia
8. Chloride
9. Coliform Bacteria

The analytes beside nitrate were included in our program to provide more data to help identify nitrate sources in Llagas Basin. Nitrite, TKN, and ammonia are either common in nitrogen sources or as a transitory nitrogen form in the ammonification/nitrification process. Analysis for these constituents may indicate areas of direct source/groundwater interaction. TKN was only included in the analysis suite for wells near the wastewater treatment plant and in our "background" areas. Ammonia was included in these areas, as well as the San Martin Special Use area. Dissolved oxygen and $\delta^{18}O$ results may help to determine the depth and/or relative "age" of the water. Stable nitrogen isotope analysis has been successfully used in other investigations to determine nitrate sources. Chlorides and coliforms were included to examine correlations between these parameters and nitrates, and make conclusions regarding their associated sources (agriculture and/or human and animal waste).

Well sampling procedures, analytical methods, sampling and laboratory QA/QC procedures (including matrix spikes and matrix spike duplicates) were described in the November 1993 revised "Quality Assurance Project Plan." Results of our sampling will be presented in the "Sample Analysis" report.

X. CONCLUSIONS

The groundwater wells selected through the process described in this report will allow for the collection of useful data as part of the Llagas Groundwater Basin Nitrate Study. The wells were selected to provide us with various types of data relevant to the study. Some of the wells were selected for the specific purpose of monitoring groundwater quality up and downgradient of different suspected nitrate source areas in the study area. Several of the wells selected for sampling are intended to provide recent data to add to historical data already compiled for those wells, thus improving the quality of our nitrate trend analysis. Other wells were picked to produce samples representative of shallow and background groundwater quality in Llagas Basin.

The data generated from the 28 wells included in our sampling program should not be used to draw conclusions about groundwater quality in all areas of the basin. Although wells were selected in different areas of the basin, and located near different types of land use areas, extrapolations about probable nitrate concentrations between sampling points should not be made. This is due to the heterogeneity of the Llagas Basin subsurface, the differences in well screening intervals throughout the area, and the incomplete knowledge concerning the vertical and horizontal extent of nitrate contamination in the Llagas Basin. We do believe that going through the structured well selection process described in this report allowed us to maximize the value of the data generated by a necessarily finite number of sampling points.

One of the next reports which will be generated for the study will present the results of the groundwater sampling for the wells selected in this report. The sampling rounds were conducted in December 1993 and March 1994; the results are currently being compiled. This upcoming report will discuss conclusions that can be drawn from the new data, continue trend analysis of the data from the appropriate wells, and discuss limitations of the conclusions to be developed from the data.

Although the data generated from our two rounds of sample collection cannot, by the nature of well water sampling, provide a definitive picture of the extent and severity of nitrate pollution in Llagas Basin, more data will help us develop a nitrate management plan for the study area. Although all the data has not been compiled, a brief look at the recent sampling results confirm that it is not uncommon for nitrate contamination in groundwater of the study area to be in excess of federally mandated drinking water standards. Clearly, nitrate occurrence in Llagas Basin needs to be actively addressed.

TABLE 1
Selected Wells for Sampling

State Well Number	Well Type[1]	Construction Details[1] (Depths and Screens[2] in Feet Below Ground Surface)	Identified Nitrate Sources in Vicinity of Well and/or Well Ranking as Applicable (If well is example or trend; range[4] in mg/l[5] of NO_3^- as NO_3^-)
10S3E01E2	Domestic	Depth = 250	Example well: 45-70[6]
10S4E18J1	Domestic	Depth = 180	Example well: 25-45
10S4E34L5	Agricultural and Domestic		Example well: 70-100
9S3E35D4	Domestic		Level 3 trend well: 25-45
10S4E17F1	Domestic	Depth = 360 Screened interval = 240-360	Level 2 trend well: <25
10S4E18G2	Agricultural	Depth = 130	Level 3 trend well: 25-45
10S3E02C5	Domestic	Depth = 200 Screened Interval = 140-200	Upgradient from food processing facility
10S3E02L1	Domestic	Depth = 187	Downgradient from food processing facility; Level 4
9S3E36B7	Domestic	Depth = 225 Screened Interval = 165-225	Downgradient of sewage disposal pits; Level 3
9S3E36C3	Domestic	Depth = 220 Screened Intervals = 100-120; 140-160; 180-220	Upgradient of sewage disposal pits; Level 3
11S4E09E1	Domestic	Depth = 400 Screened Intervals = 130-210, 250-310; 350-390	Upgradient of wastewater treatment plant; Level 4
11S4E16R2	Agricultural	Depth = 480 Screened Intervals = 270-320; 340-360; 450-470	Downgradient of wastewater treatment plant; Level 4
10S3E11D10	Agricultural and Domestic	Depth = 181 Screened Intervals = 80-100, 121-141; 161-181	Upgradient of winery; Level 4

TABLE 1
Selected Wells for Sampling
(continued)

State Well Number	Well Type[1]	Construction Details[1] (Depths and Screens[2] in Feet Below Ground Surface)	Identified Nitrate Sources in Vicinity of Well and/or Well Ranking as Applicable (If well is example or trend; range[4] in mg/l[5] of NO_3^- as NO_3^-)
10S3E12N13	Municipal and Industrial	Depth = 126 Screened Interval = 116-126	Downgradient of winery; Level 4
10S3E12M10	Municipal and Industrial	Depth = 200 Screened Interval = 120-200	Downgradient of winery; Level 4
10S4E17M10	Domestic	Depth = 210 Screened Interval = 80-120	Upgradient from dairy; Level 4
10S4E20B4	Domestic	Depth = 220 Screened Interval = 55-220	Downgradient from dairy; Level 3
9S3E34H3	Agricultural and Domestic	Depth = 200 Screened Intervals = 112-135; 178-184	Upgradient of San Martin Special Use Area; Level 4
9S3E26J8	Domestic	Depth = 175 Screened Intervals = 135-175	Upgradient of San Martin Special Use Area; Level 4
10S3E24H4	Domestic	Depth = 200 Screened Interval = 85-180	Downgradient of San Martin Special Use Area; Level 4
10S4E17E3	Domestic	Depth = 200 Screened Interval = 180-200	Downgradient of San Martin Special Use Area; Level 3
9S3E36B6	Domestic	Screened Interval = 185-225	Upgradient of San Martin Special Use Area; Level 4
10S3E01N1	Monitoring	Depth = 30 Screened Interval = 10-30	Shallow well
11S4E05K10 (Shell No. S-5)	Monitoring	Depth = 35.5 Screened Interval = 10-35	Shallow well

TABLE 1
Selected Wells for Sampling
(continued)

State Well Number	Well Type[1]	Construction Details[1] (Depths and Screens[2] in Feet Below Ground Surface)	Identified Nitrate Sources in Vicinity of Well and/or Well Ranking as Applicable (If well is example or trend; range[4] in mg/l[5] of NO_3^- as NO_3^-)
10S4E07K6	Monitoring	Depth = 237 Screened Interval = 187-237	Downgradient of agricultural field; Level 4
10S4E07E33	Domestic	Depth = 228 Screened Interval = 180-228	Upgradient of agricultural field; Level 4
10S3E18J1	Domestic		Background well—Uvas Creek area
9S3E31G5	Domestic	Depth = 55 Screened Intervals = 20-30; 45-55	Background well—Llagas Creek area

[1] Well type and construction information was obtained from the District's Water Revenue Department.
[2] Most of above wells with screening intervals reported have sanitary seals of approximately 50 feet. Some wells with reported screening intervals and all wells without reported screening intervals do not have a reported sanitary seal length.
[3] Previous sampling results were obtained from sources listed in "Review of Nitrate Data" report for this study.
[4] Concentration ranges are reported based on the highest nitrate concentration historically observed in that well, as in "Review of Nitrate Data" report.
[5] mg/l = milligrams per liter
[6] Items left blank = not available or not applicable.

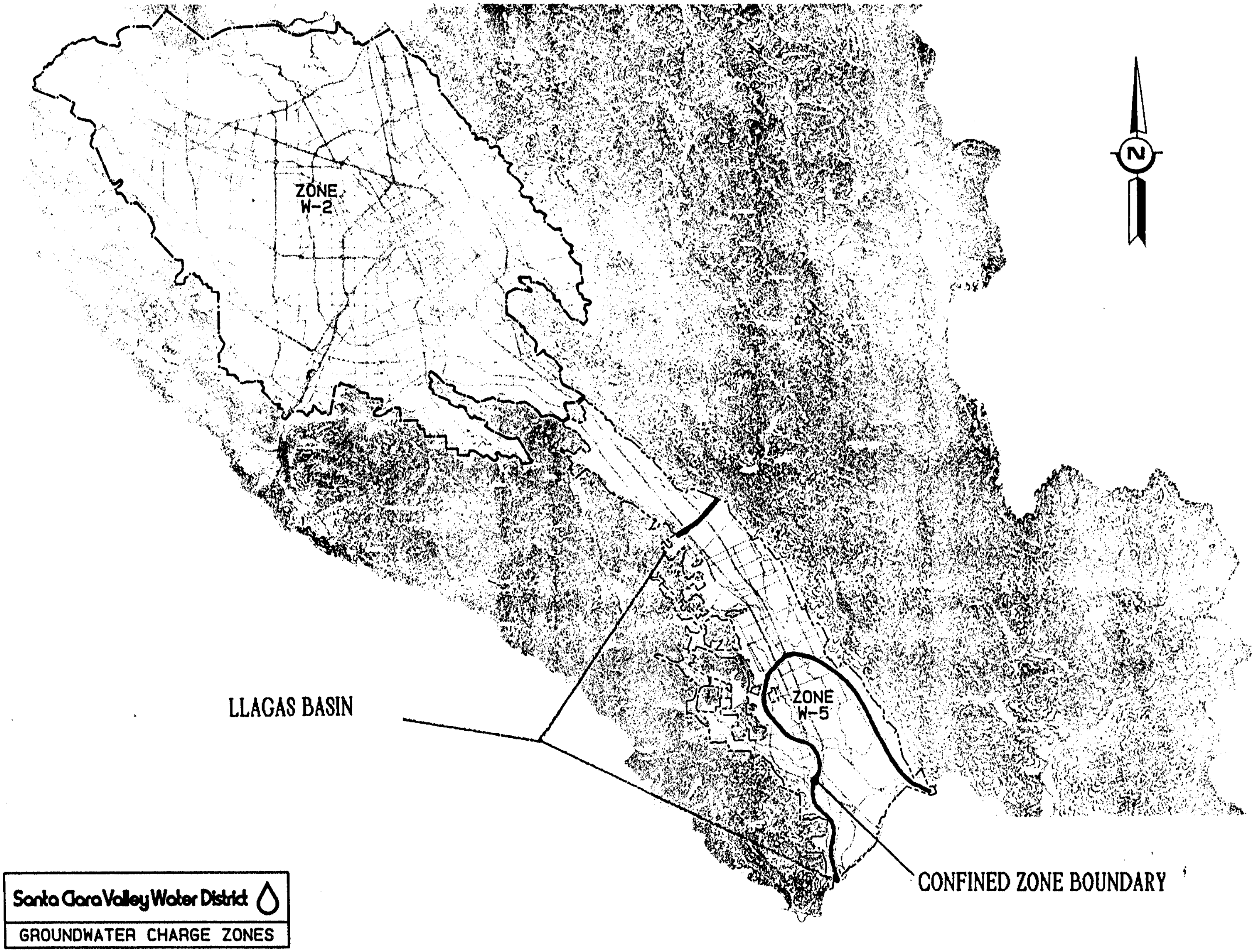
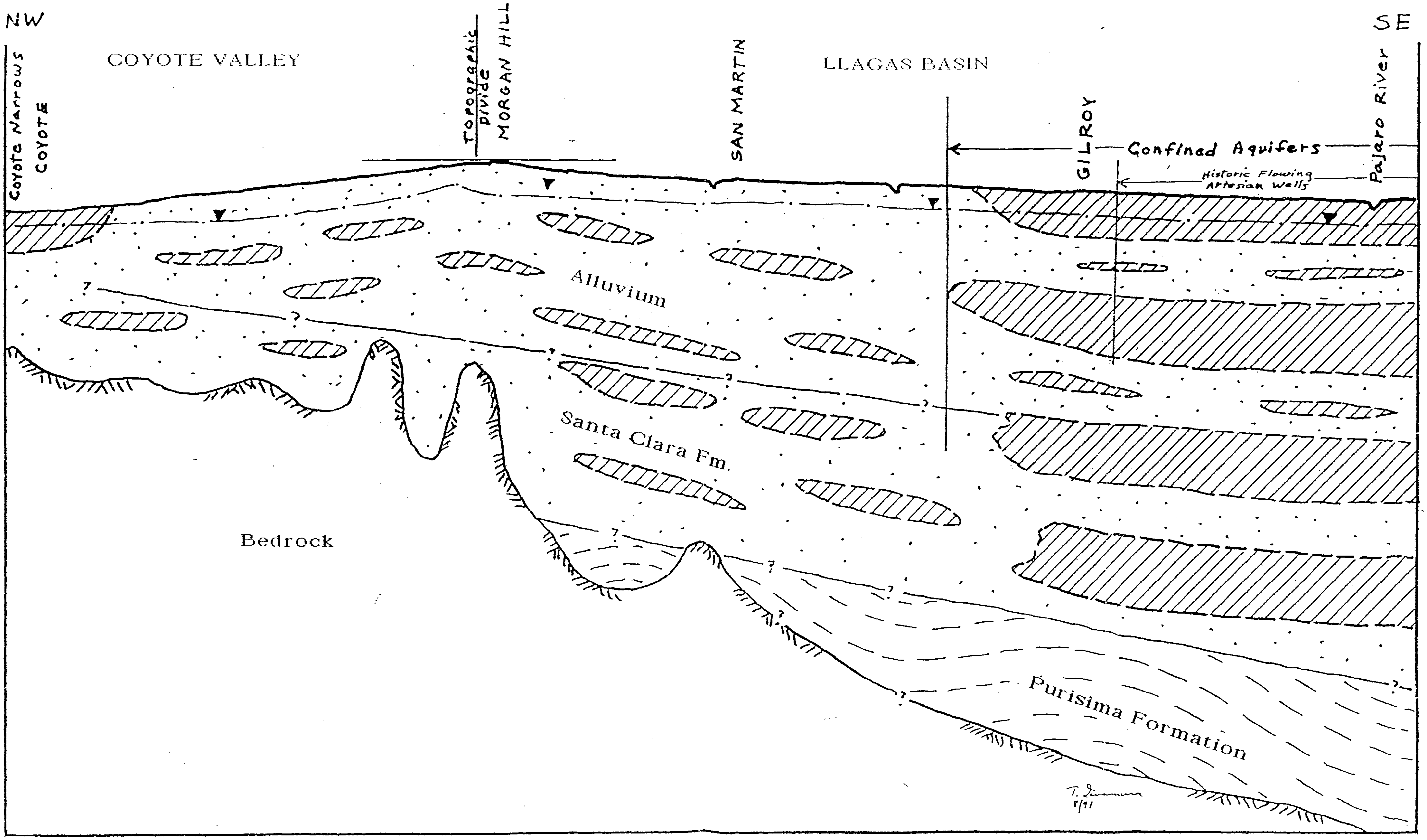


FIGURE 1: SANTA CLARA VALLEY AND LLAGAS BASIN



Not to scale

FIGURE 2: DIAGRAMMATIC CROSS SECTION
COYOTE VALLEY - LLAGAS BASIN

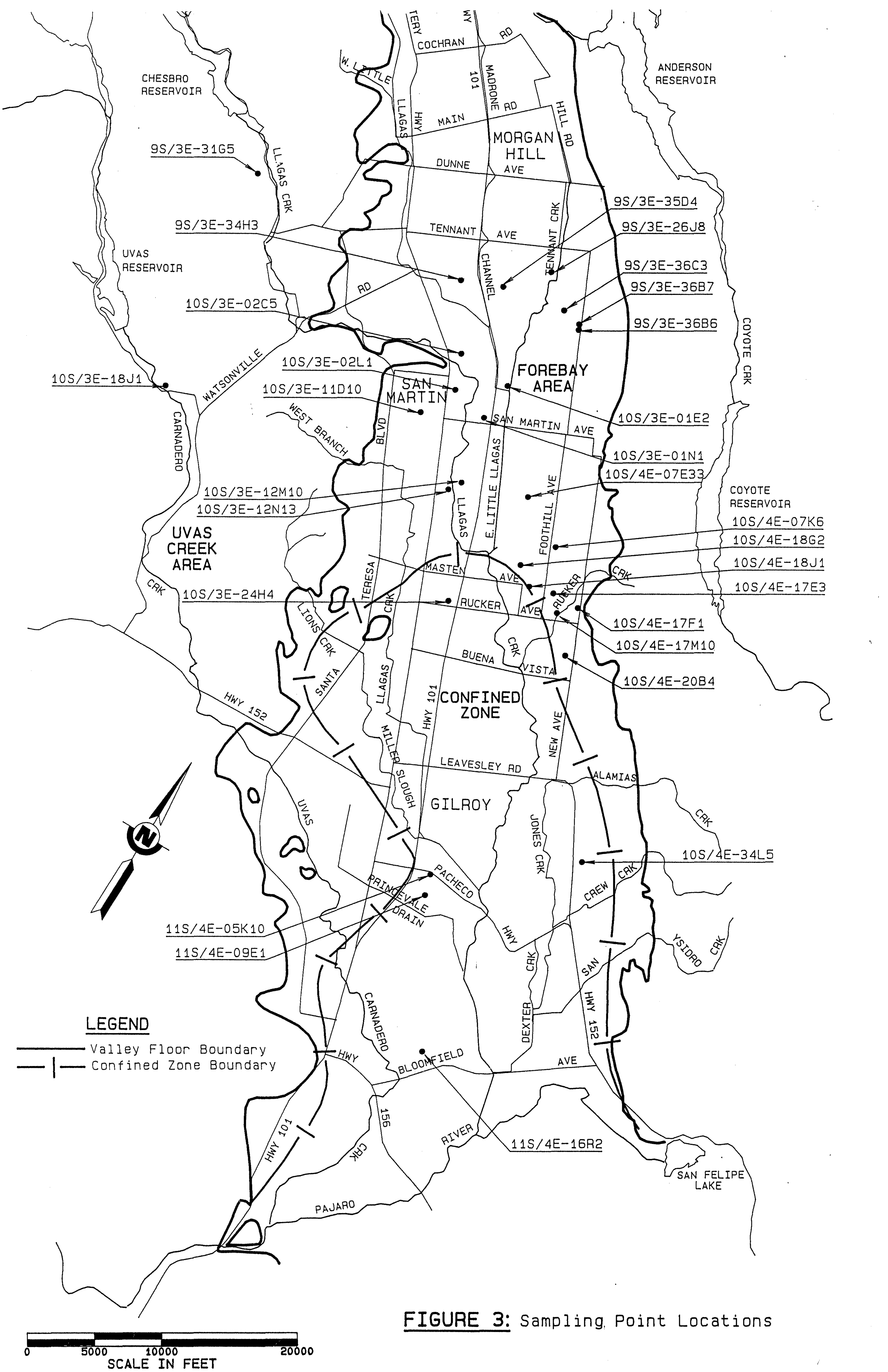


FIGURE 3: Sampling Point Locations